DARPA's Future Combat System Command and Control

Information and intelligent C2 systems are two keys to the success of FCS-equipped forces. Here, the authors outline the Defense Advanced Research Projects Agency's efforts in this area.The nexus of this system of systems must be a C2 system that provides an advanced knowledge base coupled with a creative device that will allow commanders to comprehend the science of warfare while practicing the art.

COMBAT POWER is defined as a linear function, being the sum of maneuver, firepower, and protection multiplied by leadership. In the future combat systems (FCS)-equipped force, combat power becomes an exponential equation where the power of information will raise the factors of maneuver, firepower, protection, and leadership. Therefore, information and intelligent command and control (C2) systems are key to the success of the FCS-equipped force. This C2 system must enable the FCS-equipped force to synchronize intelligence, maneuver, effects, and logistics, as well as the exchange of information with joint or combined task force C2 systems and the Army's tactical C2 systems. In short, the C2 system will enable a force that is both network- and execution-centric to employ combined arms and joint capabilities at the lowest tactical echelons.

The current FCS C2 program was a 32-month Defense Advanced Research Projects Agency (DARPA)-led effort. The program, which ran from 1 October 2000 to 31 May 2003, was to develop a rapid C2 prototype. The test's hypothesis was, "If digitization of current battlefield operating systems can substantially enhance command and control by providing better, more accurate, and timely battlefield data to today's commander and staff for decisionmaking, then a 'new' approach to Battle Command and Control implemented in the form of synthesized/analyzed information presented to the future unit cell commander will enable him to leverage opportunities by focusing on fewer unknowns, clearly visualizing current and future end states, and dictating the tempo within a variety of environments, while being supported by a significantly reduced staff."

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that would support the network-centric approach to warfare that the program proposal envisioned. This bottom-up approach focused on developing and testing a system for the lowest combined arms echelon operating within a larger battle space against an enemy with 2010 technology.

DARPA Lieutenant Colonel Gary Sauer and U.S. Army Communication-Electronics Command civilian Maureen Molz were selected as the program and deputy program managers. To build the C2 prototype, DARPA formed an operational team, a technical team, and an experimentation team. Brigadier General Huba Wass de Czege, U.S. Army, Retired, mentored the operational team, composed of U.S. Army Forces Command and U.S. Army Training and Doctrine Command (TRADOC) officers involved in the Army's Transformation and digitization efforts. In essence, the team was a reconvening of the School of Advanced Military Studies planning cell that operated in the III Corps from 1996 to 1998. Individuals joined the team on their own time and worked on the project with their command's permission as long as the work did not conflict with their assigned duties. The team focused on developing, with TRADOC and the FCS program manager, operational information exchange requirements, C2 requirements, and insight into doctrine, tactics, techniques, and procedures.

The technical team, which included personnel from academia, the Army, and industry, initially focused on the FCS C2 architecture study. The experimentation team consisted of personnel charged with developing the C2 prototype, the FCS C2 federation, and the overall plan to test the program's hypothesis. The experimentation team included a small, three-person cell of human-performance scientists from the U.S. Army Research Institute. The team was to develop and test the C2 prototype over the course of four experiments. The team built a prototype command, control, and communications system in just over 4 months and performed experiments to refine the system (spiral developed) and to gather insight.

The Commander Support Environment

The development team's first task was to define the system's qualities. The operational team designed a network-centric C2 system from the ground up, literally carte blanche. The team began with the capabilities resident in the current Army Battle Command System and added functions they thought network-centric warfare would require. Providing a networked system capable of fully integrating combined and joint arms was critical. The system had to be flexible, configurable to different staff or command positions, and tailorable to individual cognitive functions. The team recognized that people process information differently; therefore, the system had to be flexible and highly adaptable.

Based on an early draft of the FCS operation and organization, the team designed a unit cell organization consisting of manned and robotic air and ground systems to gain insight into C2 issues and for experimentation designed to explore these issues. The team chose the structure's heavy reliance on robotic systems for two reasons. First, using robotics was part of the DARPA director's guidance to the program manager. Second, robotics would provide the greatest C2 challenge to the system. The result was an execution-based C2 system that facilitated rapid mission planning and provided the commander an unprecedented level of flexibility during execution. On the technical side, the team's objectives included developing an integrated operational and C2 architecture to support the FCS unit cell, creating an initial knowledge base for the unit cell, and creating a unit cell collective intelligence to emulate a network of manned and unmanned systems.

The primary differences between the DARPA C2 prototype and the Army's current suite of tactical C2 systems are the level of automation embedded within the C2 prototype, the echelon at which this information is made available for decisionmaking, and the availability of information and data from organic assets.[1] Currently, the battalion/task force is the lowest echelon at which the Army's suite of tactical C2 systems are available to provide battlefield data, broken out by C2 system, across a set of battlefield operating systems (BOS) with limited interoperability.[2]

Because BOS breaks out this data, its presentation is stovepiped and often requires several staff officers cross-talking and comparing one another's screens to turn it into information.

In FCS C2, the program tries to take the logical next step by attempting to use advances in information technology to present all relevant battlefield information in a usable format for dynamic decisionmaking, via a single, unique, integrated graphical user interface. Instead of asking soldiers to assemble, reconcile, fuse, and place data into an operational context, that is, to convert data into information, the C2 prototype uses a knowledge base to minimize the amount of human interaction needed. The C2 prototype also uses its knowledge base to conduct dynamic planning or replanning, either fully autonomous or with user interaction, thereby turning the Army's current intense, plan-centric C2 process into an execution-based, battle-command process (see chart).

CSE in FCS C2

Understanding TRADOC's vision of the 2020 environment is paramount. TRADOC envisions creating a battle-command system that will be the first Army system to enable the art and science of battle command within a single integrated architecture. The Battle Command System (BCS) is a successful merger between the art of decisionmaking and leadership with the science of information technology. The BCS, a network-centric, web-based system operating with standard software and equipment, will exist in multiple configurations from units of action (UA) to units of employment (UE) to mobile command elements and home station operations centers, including installation, institutional, and other government or nongovernment agencies. The speculation is that unless BCS becomes more commander-driven and execution-centric, Army forces will not be able to cope with the rapidity of action and transition nor be able to exploit their full capabilities.

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The commander's preparation of the battlefield (CPB), using a BCS in which the art and science of decisionmaking and leadership are merged with information technology enables commander- and network-centric warfare. The CSE provides a single environment where an integrated and continuously updating intelligence preparation of the battlefield (IPB) or CPB is running where the commander can see it, share it, and execute immediate operational decisions based on it. This is powerful stuff.

Current Army Tactical C2 Systems	FCS C2
✓ Automated individual systems used to provide support to combined arms operations. ✓ Automation enables process. ✓ Battalion and above. ✓ Limited planning (not integrated) capability. ✓ Joint common database/server. Requires mining into functional areas. ✓ Staff does synthesis/analysis process data through deliberate decisionmaking process. ✓ Eight separate, distinct functional areas (intelligence, maneuver, fire support, air defense, mobility/countermobility, combat service support, C2, and information operations). ✓ Large staff. ✓ Deliberate linear process augmented by automation.	✓ System of systems approach. Process is embedded in automated systems relaxing human requirements. ✓ Automation is focus. ✓ Lowest FCS echelon. ✓ Dynamic planning/replanning. ✓ Knowledge base approach. ✓ Syntheses/analyses of information offloaded to HW/SW environment. Leverages knowledge base and collaborative intelligence module. ✓ Integrated functions of situational awareness, effects, battlespace management, and sustainment. ✓ Reduced staff. ✓ Time compression/dynamic planning process done by automation. Two modes: • Fully autonomous. • Commander/user intervention.

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The CSE provides the tools for the commander and staff to conduct planning as well as execution in commander-centric, distributed, mobile environments. The common relevant operating picture (CROP) is a byproduct of the CPB process, the mission received from higher headquarters, and the data and information received through sensor-fusion and the network. Commanders and staffs at all echelons can collaborate by conducting truly parallel planning, exchanging respective CROPs laterally and vertically. CROP visualization affords commanders and staff officers the agility to synchronize operations rapidly and exchange relevant information to seize opportunities and maintain initiative before and during tactical operations.

The CSE's mission workspace provides the ability to establish graphic layers to develop multiple courses of action (COAs) on a common map with common force structures. The reference task organization tool provides current organizational structures with information down to weapons system detail (range, weight, length, height, and relative combat power). The tool also allows for building new platforms and units or modifying existing systems if their capabilities change, which is extremely flexible and tailorable. This level of detail allows the display of organizations at any level and scale from individual platforms up to division- and corps-level icons. The relative combat power (RCP) of these organizations aggregates and deaggragates as the level of the organization displayed changes. (For example, a corps or joint task force commander could, if he so chose, drill down to see the location of a section of the 1st Platoon, A Company, 1st Combined Arms Battalion, 1st UE Division.) The RCP of units is tied to the status of those units and adjusts according to percentage strengths the planner establishes, which is tied to the units-on-board systems report.

The system encourages the integration of IPB products into planning, wargaming, and reconnaissance and surveillance (R&S) execution. The ability to show icons as either templated or confirmed leads to the development of R&S planning and the tasking of manned and unmanned ground and airborne platforms. The integrated sensor-fusion network then displays the results on the CROP, providing, at the least, confirmation or denial of the enemy set and, at best, targetable information. Icons can then be changed from templated to confirmed. With the sensor-shooter link thus shortened, either higher headquarters as part of shaping operations or organic assets can engage enemy platforms or units.

The route editor; graphic control measures (with smart graphics); close battle editor; surface-to-surface fires; and automated and manual attack guidance matrixes allow the user to conduct wargaming or synchronization drills either manually or in a fully automated mode. Conflict-resolution modeling, based on current doctrine models used at the U.S. Army Command and General Staff College and being further refined through DARPA experimentation, provides constructive evaluation of COAs.

The animation function enables visualization of friendly and enemy unit movement and BOS synchronization in real time and in slow motion or fast forward. The synchronization matrix (with time bar, unit tasks, and purposes) is clearly displayed and can be edited, providing a quick option for COA adjustments. Digital databases, smart graphics, and the logic underlying modified combined obstacle overlay data, including the existing traffic networks and tactical mobility corridors, ensure planners do not violate the laws of physics. Systems perform as they will in a battlefield environment. Smart ground combat models, such as a restrictive fire line, are tied to a unit's movement or to time allowing effective multiunit synchronization and active fratricide prevention. The route planner provides auto-generated routes simply by clicking two or more points. However, the user can also manually plan routes when the situation dictates. When a unit is told to move a certain distance and conduct an attack at a specific time, the synchronization matrix will show whether the unit can get there in the time allocated, displaying the task in red.

Some programmed characteristics are associated with specific units resident in the system's knowledge base. The unit's footprint—the actual space it occupies on the ground—is based on the task at hand; default formation; sensor and weapons systems ranges; and so on. Footprints exist and vary as affected by terrain. Just as when a unit is given a mission and the system generates a route and formation to enable the unit to best accomplish the mis-

US Army

The DARPA FCS C2 experimental vehicle mockup.

The system's functionality gets right to the heart of the BCS objective of merging the art of decisionmaking and leadership with the science of information management and its technological aspects in a commander- and network-centric process. DARPA CSE integrates the best parts of the traditional military decisionmaking process without the lock-step rigidness that causes commanders and staffs to abandon it when faced with critical time constraints.

sion, the system will generate a route to best accomplish the mission when aerial sensor platforms receive a mission, such as reconnaissance, named area of interest, and sensor (moving target indicator, search and rescue, or direct-view optics). The ability to drag and drop or copy individual graphics or entire COAs allows rapid development of multiple COAs. The on plan/off plan monitoring encourages the user to identify problems and to develop contingency COAs by a user even during execution.

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The key to FCS-system survivability is to develop the situation out of contact and to assure that when close combat occurs it is at a time and place of the user's choice. Therefore, the shaping fight is instrumental in setting the conditions of success for the maneuver force. IPB/CPB identifies the enemy COAs that are most likely to be dangerous and vets the enemy's situation template with the latest

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sensor-fusion picture from organic to national asset sources. The commander and staff analyze enemy high-value targets and develop high-payoff target lists (HPTL) for each COA. The COA developed should use the latest and best information. The higher headquarters identifies targets best engaged by higher headquarters assets (such as air interdiction, close air support (CAS), Comanche) and passes down the task best done by subordinates.

The attack guidance matrix (AGM) assists in developing fire planning and execution of the fire plan. AGM facilitates networked fires by conducting target pairing and shortening the sensor-shooter link. The AGM is developed based on the HPTL, the enemy forces arrayed in sector, and the mission. In developing the AGM, the user matches the most effective munitions (the ones with the highest probability of kill) against the priority targets on the HPTL. Targets might include air defense systems (to protect unmanned aerial vehicles and so on), long-range artillery, and direct fire systems (tank/antitank). The AGM binds the sensor network to the network of fires through an automated system of target weapons pairing. The AGM is the key technology that allows for compression of the traditional BOS by enabling the commander access to organic sensor data and a unitary fire control system capable of employing line of sight, beyond line of sight, non-line of sight, and joint fires.

Targeting is built around the decide, detect, deliver, and assess methodology (D3A). The decide process is established in the HPTL and AGM build. The detect phase is R&S development and execution (sensor fusion, air and ground reconnaissance, and counter fire radar). The deliver phase is where the commander melds and applies art and science through assigned autofire missions, initiated when a system is detected, set in the AGM. This is the commander's tactical read and synchronized ground maneuver of manned and unmanned systems. The final assess process is battle damage assessment and reporting (BDAR). Every indirect-fire engagement requires BDAR to ensure that the desired effect on the target was achieved and to decide whether reengagement is necessary. The CSE enables D3A through the integrated CROP, AGM, auto-BDAR cueing (the tasking of the nearest available unemployed reconnaissance asset to the target) and ability to plot tracks for Loiter Air Munitions.

The Road Ahead

The DARPA FCS C2 commander's support environment project provides a clear road ahead for future experimentation and effort. No other C2 project has progressed as far on the development pathway to the transformed Army's future needs. To provide commanders with the best, most accurate, and timely information, a fusion of sensors, shooters, machines, and humans is necessary. The nexus of this system of systems must be a C2 system that provides an advanced knowledge base coupled with a creative device that will allow commanders to comprehend the science of warfare while practicing the art. The CSE is a solid step forward. ***MR***

NOTES

1. The Army's current suite of tactical C2 systems includes the All-Source Analysis System, the Maneuver Control System, the Advanced Tactical Field Artillery System, the Air and Missile Defense Work Station, and the Combat Service Support Control System.
2. The battlefield operating systems include intelligence, maneuver, fire support, air defense, mobility/countermobility/survivability, combat service support, and command and control.

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